

## QUARKS

The  $u$ -,  $d$ -, and  $s$ -quark masses are estimates of so-called “current-quark masses,” in a mass-independent subtraction scheme such as  $\overline{\text{MS}}$  at a scale  $\mu \approx 2$  GeV. The  $c$ - and  $b$ -quark masses are the “running” masses in the  $\overline{\text{MS}}$  scheme. For the  $b$ -quark we also quote the 1S mass. These can be different from the heavy quark masses obtained in potential models.

**u**

$$I(J^P) = \frac{1}{2}(\frac{1}{2}^+)$$

$$\begin{aligned} m_u &= 2.3^{+0.7}_{-0.5} \text{ MeV} & \text{Charge} &= \frac{2}{3} e & I_z &= +\frac{1}{2} \\ m_u/m_d &= 0.38-0.58 \end{aligned}$$

**d**

$$I(J^P) = \frac{1}{2}(\frac{1}{2}^+)$$

$$\begin{aligned} m_d &= 4.8^{+0.5}_{-0.3} \text{ MeV} & \text{Charge} &= -\frac{1}{3} e & I_z &= -\frac{1}{2} \\ m_s/m_d &= 17-22 & & & & \\ \bar{m} &= (m_u+m_d)/2 = 3.5^{+0.7}_{-0.2} \text{ MeV} & & & & \end{aligned}$$

**s**

$$I(J^P) = 0(\frac{1}{2}^+)$$

$$\begin{aligned} m_s &= 95 \pm 5 \text{ MeV} & \text{Charge} &= -\frac{1}{3} e & \text{Strangeness} &= -1 \\ m_s / ((m_u + m_d)/2) &= 27.5 \pm 1.0 & & & & \end{aligned}$$

**c**

$$I(J^P) = 0(\frac{1}{2}^+)$$

$$m_c = 1.275 \pm 0.025 \text{ GeV} \quad \text{Charge} = \frac{2}{3} e \quad \text{Charm} = +1$$

**b**

$$I(J^P) = 0(\frac{1}{2}^+)$$

$$\text{Charge} = -\frac{1}{3} e \quad \text{Bottom} = -1$$

$$\begin{aligned} m_b(\overline{\text{MS}}) &= 4.18 \pm 0.03 \text{ GeV} \\ m_b(1S) &= 4.66 \pm 0.03 \text{ GeV} \end{aligned}$$

**t**

$$I(J^P) = 0(\frac{1}{2}^+)$$

$$\text{Charge} = \frac{2}{3} e \quad \text{Top} = +1$$

Mass (direct measurements)  $m = 173.07 \pm 0.52 \pm 0.72$  GeV [<sup>a,b</sup>]  
 Mass ( $\overline{\text{MS}}$  from cross-section measurements)  $m = 160^{+5}_{-4}$  GeV [<sup>a</sup>]  
 $m_t - m_{\bar{t}} = -0.6 \pm 0.6$  GeV (S = 1.2)  
 Full width  $\Gamma = 2.0 \pm 0.5$  GeV  
 $\Gamma(Wb)/\Gamma(Wq(q = b, s, d)) = 0.91 \pm 0.04$

### **t-quark EW Couplings**

$$\begin{aligned} F_0 &= 0.70 \pm 0.05 \\ F_- &= 0.32 \pm 0.04 \\ F_+ &= -0.017 \pm 0.028 \\ F_{V+A} &< 0.29, \text{ CL} = 95\% \end{aligned}$$

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<b>t DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	Confidence level	$p$ (MeV/c)
$W q (q = b, s, d)$		—	
$W b$		—	
$\ell \nu_\ell$ anything	[c,d] (9.4±2.4) %	—	
$\gamma q (q=u,c)$	[e] < 5.9 $\times 10^{-3}$	95%	—
<b><math>\Delta T = 1</math> weak neutral current (T1) modes</b>			
$Z q (q=u,c)$	$T1 [f] < 2.1$	$\times 10^{-3}$	95%

**b' (4<sup>th</sup> Generation) Quark, Searches for**

- Mass  $m > 190$  GeV, CL = 95% ( $p\bar{p}$ , quasi-stable  $b'$ )  
 Mass  $m > 199$  GeV, CL = 95% ( $p\bar{p}$ , neutral-current decays)  
 Mass  $m > 128$  GeV, CL = 95% ( $p\bar{p}$ , charged-current decays)  
 Mass  $m > 46.0$  GeV, CL = 95% ( $e^+ e^-$ , all decays)

**t' (4<sup>th</sup> Generation) Quark, Searches for**

- Mass  $m > 685$  GeV, CL = 95% ( $p\bar{p}$ ,  $t'\bar{t}'$  prod.,  $t' \rightarrow W q$ )  
 Mass  $m$

**Free Quark Searches**

All searches since 1977 have had negative results.

**NOTES**

[a] A discussion of the definition of the top quark mass in these measurements can be found in the review ‘‘The Top Quark.’’

LINKAGE=REV

[b] Based on published top mass measurements using data from Tevatron Run-I and Run-II and LHC at  $\sqrt{s} = 7$  TeV. Including the most recent unpublished results from Tevatron Run-II, the Tevatron Electroweak Working Group reports a top mass of  $173.2 \pm 0.9$  GeV. See the note ‘‘The Top Quark’’ in the Quark Particle Listings of this Review.

LINKAGE=TPM

[c]  $\ell$  means  $e$  or  $\mu$  decay mode, not the sum over them.

LINKAGE=LPE

[d] Assumes lepton universality and  $W$ -decay acceptance.

LINKAGE=LPF

[e] This limit is for  $\Gamma(t \rightarrow \gamma q)/\Gamma(t \rightarrow W b)$ .

LINKAGE=TD3

[f] This limit is for  $\Gamma(t \rightarrow Z q)/\Gamma(t \rightarrow W b)$ .

LINKAGE=TD2

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